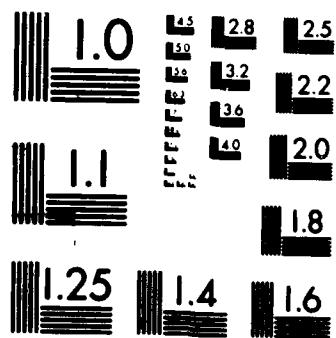


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NEUROTRANSMITTERS AND INTRAC (U) AT AND T BELL LABS  
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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Research has been carried out in the three areas outlined below.			
<p>I. Excitatory amino acid responses in adult mammalian hippocampal neurons. This topic has become the focus of extensive research due to its possible relationship to short term memory. We have made the first measurements of calcium ion changes in these cells using fluorescence imaging techniques, and have demonstrated a long lasting response involving Ca flux induced after conditioning input to the cells. II. The developmental time course in culture of ion channels and transmitter sensitivity in cerebellar Purkinje neurons. We have demonstrated differential soma-dendritic responses to depolarization and the neurotransmitter glutamate in these neurons. Parallel immunocytochemical experiments using a number of antibodies have demonstrated the development of antigens in culture in comparison to in vivo development. III. Neuromodulation of synaptic efficacy in an invertebrate preparation that may be a useful model system for the actions of histamine in the CNS.</p>			
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## SUMMARY

Significant progress has been made in the three areas outlined below.

1. Excitatory amino acid responses in adult mammalian hippocampal neurons that are a possible basis for short term memory. Measurements have incorporated fluorescence imaging for calcium ion changes and electrophysiological techniques.
2. The developmental time course in culture of ion channels and transmitter sensitivity in cerebellar Purkinje neurons.
3. Neuromodulation of synaptic efficacy in an invertebrate preparation that may be a useful model system for the actions of histamine in the CNS.

## RESEARCH OBJECTIVES

The primary objective of this research is to elucidate how endogenous neuroactive substances, neurotransmitters, neuromodulators, affect brain function. Nerve cells are the functional units of the brain, and changes in neuronal activity are ultimately expressed through modifications in membrane conductances and levels of intracellular messengers such as calcium ion. We have therefore focused our attention on examining the mechanisms by which neuroactive substances alter these conductances and messenger levels.



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## STATUS OF RESEARCH

- A. Action of excitatory amino acids on Cal neurons from mammalian hippocampus.

Spatially resolved measurements of intracellular free calcium,  $[Ca^{2+}]$ , and the changes produced by excitatory amino acids, have been made for the first time in neurons isolated from adult mammalian brain. We report the induction of extremely long lasting (minutes) gradients of  $Ca^{2+}$  in the apical dendrites of hippocampal CA1 neurons following brief (1-3 s), local application of either glutamate or NMDA. These gradients reflect the continuous flux of  $Ca^{2+}$  into the dendrite. The persisting gradients, but not the immediate, transient response to the agonists were abolished by pretreatment with the protein kinase-C inhibitor, sphingosine. Expression of the long lasting  $Ca^{2+}$  gradients generally required priming, or conditioning, exposures to the excitatory agonist. That is, the initial application triggered a transient Ca elevation that recovered within 1 minute; whereas subsequent, identical applications induced the longer responses. Our findings demonstrate that successive applications of glutamate and NMDA elicit prolonged rises in intracellular  $Ca^{2+}$  that persist beyond the period of direct agonist-receptor interaction, and possibly reflect the activation of dormant Ca channels by the stimulus paradigm.

This coupling between NMDA receptor activation and long-lasting intracellular  $Ca^{2+}$  elevation could underly certain use-dependent modifications of synaptic responses in hippocampal CA1 neurons. Most importantly, we believe that the events that we have described are at least part of the mechanism underlying associative long term potentiation in the hippocampus, a phenomenon widely studied as a model for short term memory. This work was a collaborative study with Robert Wong (Columbia U.) and Wytse Wadman (U. Amsterdam).

neurons.

Culture conditions have been worked out whereby cerebellar Purkinje neurons are maintained for periods of 60-80 days and develop extensive dendritic tree structures. Identity and morphology of these cells have been established by antibody staining techniques applied to both tissue cultures and to neurons isolated acutely from the brains of animals at various ages. Using electrical recording with whole-cell patch electrodes we have determined the developmental timing of the appearance of membrane Na and K channels as well as neurotransmitter activated channels. We have made the first thorough comparison of these timings between *in vivo* and *in vitro* development.

Using the imaging techniques developed in this lab in 1984, we have made measurements of internal  $\text{Ca}^{2+}$  changes in these cells during electrical and chemical stimulation. We have shown that the neurons, even in culture conditions, localize Ca channels on the dendrite membrane.

### C. Invertebrate neuron model for studying synaptic plasticity.

Using the methods of Schacher et al. [1], we cultured identified neurons from the marine mollusc *Aplysia*, in which different forms of synaptic plasticity have been observed [2]. We reconstructed connections between neurons by co-culturing identified neurons. Using physiological criteria, we established that these connections were similar to those made by the neurons *in vivo*. We then constructed a hybrid circuit in order to study a particular form of synaptic plasticity in culture. Two neurons which are synaptically connected *in vivo* (C2 and C4) were co-cultured with a third neuron

(L10), which does not form synaptic connections with them *in vivo*. We predicted, however, that L10 would form connections with the other two neurons in culture because it shares two properties with a neuron (B18) that is synaptically connected to C2 and C4 *in vivo*: it is cholinergic, and is inhibited by histamine. Since B18 and L10 are part of different circuits in which presynaptic inhibition is observed *in vivo* [3,4], we predicted that this form of synaptic plasticity would be observed in our cultured hybrid circuit.

We established that presynaptic inhibition occurred in the hybrid circuit, i.e., the connection from L10 to C4 could be inhibited by neuron C2's action on the presynaptic neuron, L10. Firing C2, or applying histamine, hyperpolarized L10 and reduced the size of the postsynaptic potential (PSP) which L10 induced in C4. Hyperpolarization of L10, which is known to reduce the release of its transmitter *in vivo*, also reduced the size of the PSP it induced in C4 in culture. Cimetidine, a drug which blocks histaminergic responses in *Aplysia* [5], blocked the hyperpolarization that C2 or histamine induced in L10, and also prevented histamine from reducing the PSP which L10 induces in C4.

Our studies have demonstrated that a form of synaptic plasticity, presynaptic inhibition, can be reconstructed *in vitro*. In addition, extensive work on L10 *in vivo* suggests that the presynaptic inhibitory actions of histamine are due to reductions in the intracellular levels of calcium in L10 [5]. Since one can directly visualize the processes of L10 in culture, we can use this model system and our techniques for observing intracellular calcium levels to study more directly the role of calcium in this form of synaptic plasticity.

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